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Research into the Characterization of Brackish Water and Disposal of Desalination Reject Water in Saline Aquifers and Depleted Oil and Gas Reservoirs

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Research into the Characterization of Brackish Water and Disposal of Desalination Reject Water in Saline Aquifers and Depleted Oil and Gas Reservoirs

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Abstract

Brackish groundwater is a valuable "drought-proof" resource that is plentiful in much of Texas. If treated by available desalination technologies, brackish groundwater resources could help many regions of Texas cope with pressing water shortages. If put to non-potable uses such as waterflooding, streamflow augmentation, and landscape irrigation, brackish groundwater could free up substantial amounts of drinking water supplies now dedicated to these uses.

In 2007, the Texas Legislature passed landmark legislation that should provide greatly expanded opportunities to beneficially use concentrates from the desalination of brackish groundwater or to streamline the disposal as a waste product. House Bill 2654 (passed in the 80th Legislative session) has the promise of making it substantially easier to manage concentrates that result from the desalination of brackish groundwater. The bill authorizes the Texas Commission on Environmental Quality to issue a general statewide permit that allows disposal of non-hazardous brine from desalination operations into Class I injection wells. The bill also streamlines the process of using the concentrates in Class II injection wells for enhanced oil and gas recovery operations.

However, more still needs to be done in two key areas:

- Learning more about the chemical traits of brackish groundwater in specific circumstances to ensure that concentrates from desalting these resources are not a hazardous waste,
- Continuing to develop and implement technologies and management strategies that make these programs most cost-efficient.

Introduction

In 2003, the Texas Water Development Board (TWDB) reported that Texas contains more than 2.7 billion acre feet (AF) of brackish groundwater. Of this amount, experts estimate that more than 780 million AF could be treated through desalination for beneficial use.

The potential benefits of treating brackish groundwater are significant. For example, researchers with the Global Petroleum Research Institute at Texas A&M University suggest that the salvage and reuse of brackish groundwater, as well as produced waters, can reduce disposal costs by roughly $3,500 per day at an individual well field, especially if these treated waters are used to augment or replace municipal water supplies. Experts also suggest that the treatment and beneficial use of brackish groundwater may create significant opportunities for the oil exploration industry. Treating brackish groundwaters so they can be used for waterflooding (to enhance oil and gas production) will free up fresh water now used for this purpose. Recent research from the University of Texas at Austin (Nicot, Mace & Chowdhury, 2005) suggests that brackish groundwaters (and oilfield produced waters) can be treated and or managed so problems related to scaling or the mobilization of clays can be avoided, thus allowing them to be used for waterflooding throughout Texas.

In 2005, TWDB funded three demonstration projects to desalinate brackish groundwater at inland locations. These demonstration sites, located in Kenedy, Karnes, and Tom Green counties, will provide practical examples of how desalination projects can be effectively managed, including strategies to deal with concentrate issues. These projects are expected to be in operation within the next five years. It should be noted the Texas cities of Sherman, Fort Stockton and El Paso, have used desalination as a water supply strategy for several years.

Treating and beneficially using brackish groundwater is being implemented in Texas, throughout the United States, and internationally. Recently, the Consortium for Hi-technology Investigations in Water and Wastewater (CHIWAWA) was formed as a cooperative effort between the Texas AgriLife Research and Extension Center at El Paso, Texas AgriLife Research, the Texas AgriLife Extension Service, the University of Texas at El Paso, New Mexico State University, the U.S. Bureau of Reclamation, the American Water Works Association Research Foundation, and the El Paso County Water Improvement District. One of the leading goals of CHIWAWA is to study issues broadly related to the desalination and management of brackish and saline groundwater resources. On a national level, the U.S. Bureau of Reclamation recently opened the Brackish Groundwater National Desalination Research Facility in Alamogordo, New Mexico. The facility is a joint effort between Reclamation and New Mexico State University but will also explore brackish groundwater issues related to Texas, the Southwest, and arid regions of the United States.

There is also compelling evidence that the desalination of brackish groundwater may soon become commonplace throughout Texas. In 2007, a 27 million gallon per day plant opened in El Paso to treat brackish groundwater via desalination, making it one of the largest such efforts in the world. That project is a joint effort between El Paso Water Utilities, the Fort Bliss Army Base, the City of El Paso, and other partners. On a global scale the desalination of brackish groundwater is being studied as a potential water resources solution in arid areas in the Middle East, Africa, and Asia.

Federal Regulations

State and federal regulation of concentrate disposal often limits reuse of produced waters. Key concepts of these regulations are covered here.

Regulation of Treatment By-Products

Federal regulation of the management of concentrates and brines resulting from the desalination of brackish groundwater and oilfield-produced water is governed by the Safe Drinking Water Act of 1974, which gave the United States Environmental Protection Agency (EPA) authority to manage the disposal and reuse through the Underground Injection Control (UIC) program. These rules are covered in Part C, Sections 1421-1426. The intent of the UIC program is to protect drinking water aquifers by ensuring that materials injected into geologic formations are placed and contained beneath the lowest source of drinking water, thus ensuring that groundwater contamination will not occur.

In the UIC program, regulations have been established for different types of underground injection wells:

- Class I wells can be used to place industrial and municipal wastes into isolated geologic formations beneath the lowest source of drinking water. Class I wells are the most strictly regulated by EPA under the Safe Drinking Water Act (SDWA) and the Resource Conservation and Recovery Act (RCRA).
- Class II wells can be used to inject brines and other fluids associated with oil and gas production.
- Class III wells can be used to inject fluids associated with the solution mining of minerals.
- Class IV wells involve the disposal of hazardous or radioactive wastes into or above an underground source of drinking water and are generally prohibited.
- Class V wells are those that inject non-hazardous fluids into or above an underground source of drinking water and may include onsite wastewater systems, leach fields, other disposal systems, and drainage wells.

In most of the United States including Texas, Class II wells are used to inject water produced as part of oil and gas exploration and production. Types of Class II wells include those used for waterflooding and enhanced oil and gas recovery (Class II-R) and disposal (Class II-D). Class II-R wells are considered a beneficial use.

Two aspects of the discharge of produced water are described in Subpart C of Section 40 of the Code of Federal Regulations (CFR), Part 435 as enforced by the Railroad Commission of Texas (RRC) under a delegation agreement with EPA. At locations in Texas west of the 98th meridian (which roughly runs from Wichita Falls to Austin to Brownsville), produced water with oil and grease concentrations of less than 35 mg/l can be discharged into navigable waters if it is of a sufficient quality to be used for livestock watering or agricultural uses.

How Texas HB 2654 Changes Regulatory Environment

In 2007, the Texas Legislature passed House Bill 2654, which has the promise of making it substantially easier to manage concentrates that result from the desalination of brackish groundwater. HB 2654 amends Chapter 27 of the Texas Water Code and Chapter 361 of the Texas Health and Safety Code by streamlining regulatory processes that in the past have limited the use of certain types of injection wells for the disposal of desalination byproducts. It adds Section 361.086 of the Texas Health and Safety Code which creates a general permitting process that can be applied to several facilities where brackish groundwater is treated with desalination.

The bill authorizes TCEQ to issue a general statewide permit that allows for the disposal of non-hazardous brine from desalination operations into Class I injection wells. To obtain such a permit, applicants must meet all the statutory and regulatory requirements otherwise needed to obtain a license for a Class I injection well. Under provisions of the bill, permits can be issued for up to 10 years, but can be suspended or revoked during this period if regulatory agencies judge that compliance is not satisfactory. The purpose of the general permit is to streamline the permitting process. If the applicant can meet all the requirements, the application can be authorized under the general permit (rather than being processed individually under a site-specific permit). The general permit will ensure that disposal construction and operating standards can be readily enforced, and will assure safeguards are in place to prevent pollution of ground and surface waters.

In many cases, permits are requested to use brines produced as a byproduct of desalinating brackish groundwater as injection fluids for the enhanced recovery of oil and natural gas in Class II injection wells. HB 2654 streamlines the permitting process of the Railroad of Commission of Texas by eliminating the requirement to obtain a permit for the disposal of these fluids from the TCEQ. If these brines involve radioactive materials, they will also be regulated through the Texas Radiation Act.

Other Texas Regulatory Programs

The RRC is the primacy agency that enforces the Underground Injection Control (UIC) Class II program in Texas. In broad terms, RRC programs are very similar to EPA requirements. Minor differences center on the area of review (AOR) process and the mechanical integrity and testing (MIT) program. For Class II-D wells, the RRC and the TCEQ specify the distance that must be present between UIC wells and underground sources of drinking water (for example, in clay and shale formations there must be a vertical distance of 250 feet between the base of the underground source of drinking water and the injection zone).

Water Quality Characteristics of Brackish Groundwaters in Texas

Generally speaking, brackish groundwater exhibits salinity concentrations from 1,000 to 10,000 milligrams per liter (mg/l). TWDB recently reported that Texas contains more than 2.7 billion acre feet (AF) of brackish groundwater (Kalaswad et al, 2004). Brackish water resources occur in 26 of Texas’ 30 major and minor aquifers and in all 16 regional water planning areas. The largest amount of brackish groundwater (417 million AF) is present in South Central Texas (planning region L), while the Gulf Coast Aquifer contains the most brackish groundwater (522 million AF). When considered on a statewide basis, there is roughly twice as much slightly brackish groundwater (1,000 mg/l to 3,000 mg/l total dissolved solids or TDS) than moderately brackish groundwater (3,000 to 10,000 mg/l of TDS).

A comprehensive 2003 study by LBG-Guyton utilized a ranking scheme that incorporated water availability, productivity, and source water production costs for brackish aquifers throughout Texas. Results of their analyses suggest that seven of the 16 regional water planning areas scattered throughout much of the state have sufficient quantities of brackish water to meet projected water needs. Put another way, the research suggests that more than 780 million AF per year could be treated through desalination for beneficial use.

Specific groundwater quality traits may influence the extent to which concentrates from the desalination of brackish aquifers may be treated as a freshwater resource or a hazardous waste. Some of the most important parameters include naturally-occurring heavy metals (especially arsenic) and naturally-occurring radionuclides. The key is to ensure that water quality levels do not exceed standards set by the Resource Conservation and Recovery Act and/or the Safe Drinking Water Act standards. In addition, naturally-occurring levels of total dissolved solids and sulfates (as well as other contaminants) may decrease the performance of membranes, even though they may fall within the range of acceptable levels found in the SDWA.

Concentrate Management

Historically, substantial volumes of brine resulting from the desalination of brackish groundwater have been disposed of in oil and gas formations throughout Texas with few significant environmental problems (Nicot & Chowdhury, 2005). In the 1990s, Marathon Oil Company evaluated a plan to use desalinated water on its Yates Field in West Texas.

Because formation pressures have been lowered in many formations due to extensive oil and gas production, Nicot & Chowdhury (2005) suggest there is an opportunity to inject large volumes of produced water and brackish groundwaters that have been treated by desalination into oil-producing geology formations throughout much of Texas to increase energy production. They conclude that treating brackish groundwater and then injecting desalination concentrates into depleted oil and gas fields using existing deep wells may be a feasible alternative.

Burnett (2004) suggests that brackish groundwaters with concentrations of less than 10,000 mg/l total dissolved solids are the best candidates for treatment when waters will be used for purposes other than drinking water. Burnett & Veil (2004) contend that efforts to treat brackish groundwater with desalination processes may require less pretreatment than oilfield-produced waters. Burnett & Veil also suggest that reverse osmosis technologies will often produce higher quality concentrates, because pretreatment will remove materials that might plug filters. These concentrates could then be put to beneficial uses including irrigation and habitat restoration.

Technologies most often used in desalination include membrane systems and evaporation-based methods. Membrane systems are most often used in smaller plants for the treatment of brackish groundwater. Pressure-driven membrane processes include microfiltration, ultrafiltration, nanofiltration, and reverse osmosis. Alternatively, electro-potential membrane systems include electrodialysis and electrodialysis reversal. Nationally, Fraser (2005) estimates that RO is used in more 72% of desalination plants treating brackish waters with salinities of less than 3,500 milligrams per liter (mg/L).

As of 2004, Texas inland desalination facilities had a combined capacity to treat 52 million gallons per day (GPD) of brackish and saline groundwaters, a significant increase from a capacity of less than 10 MGD in 1995. Viewed from another perspective, Texas had 28 operating desalination plants in 2002, third nationally behind only Florida and California (Mickley, 2004). Methods now used to dispose of concentrate resulting from the desalination of brackish waters include the use of evaporation ponds, discharges to surface water, underground injection, and land application.

In Texas, David Burnett and colleagues with the Texas Water Resources Institute have developed a mobile desalination unit that can be used to demonstrate how brackish water can be treated at remote locations. To-date, the trailer has demonstrated at sites throughout Texas and the Southwest. The goal is to be able to treat brackish and saline groundwater so it can be used for irrigation water (i.e., water quality with less than 500 mg/l of total dissolved solids and less than 0.05 mg/l of hydrocarbons).

Economic Issues

Burnett & Pankratz (2004) note that brine disposal represents a significant fraction of the cost of operating a desalination facility, especially if brines have to be hauled over large distances before disposal. Average costs to dispose of brines from the desalination of brackish groundwaters and oilfield-produced waters in Texas range from $24 to $40 per 1,000 gallons.

Nicot & Chowdhury (2005) examined the economics related to the disposal of treated waters from desalination in injection wells. Results suggest that the costs to permit, develop, and operate these Class II wells may decrease as technology improves and as regulatory programs become more accommodating to innovative disposal strategies.

Gene Theodori of Sam Houston State University is now working with David Burnett of the Global Petroleum Research Institute and William Fox of TWRI to develop empirical estimates of cost-savings that can be achieved through the implementation of systems that reuse brackish and saline waters. The project involves assessing the extent to which the public may be willing to accept non-conventional sources of water (i.e., sources produced by the desalination of oilfield-produced waters and brackish groundwater) in their communities. A focus of theses studies is to determine the extent people view these resources as a resource rather than a risk.

Summary and Recommendations

Recently passed legislation, specifically Texas House Bill 2654, should make it easier to obtain permits to treat brackish groundwater via desalination. It may be useful to examine other policies that may need to be modified to expand the opportunities to treat and manage inland waters with desalination methods.

The use of desalination to treat brackish groundwater waters has the potential to supply new sources of water that may help Texas meet growing demands. However, the fact remains that the potential use of brackish groundwater is largely unmet. In the near future, Texas must take firm steps to substantially increase the amount of water produced through desalination if state water planning goals will be met. *Water for Texas* (the state water plan) suggests that 10% of water supplies in Texas will come from reuse by the year 2020).

One of the most-pressing research needs is to gather data on specific contaminants present in Texas brackish groundwater systems. The goal is should be to identify site-specific circumstances in which groundwaters treated by desalination may produce byproducts that could be classified as hazardous wastes or that may violate provisions of the Safe Drinking Water Act. Similarly, another pressing need is to identify brackish groundwater formations that could most easily produce water for beneficial use without posing water quality risks.

Another major research need is to develop improved technologies and management strategies to deal with the treatment of brackish groundwater. Research also needs to be conducted to continue to develop and field-test innovative technologies and management systems that can facilitate the desalination of brackish groundwater in the most cost-effective manner.

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